The Battery Program at Lawrence Berkeley National Lab

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CPUC Energy Storage Workshop

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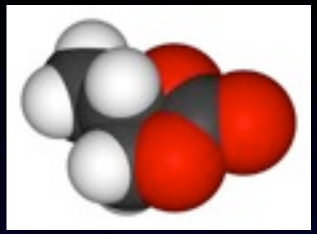
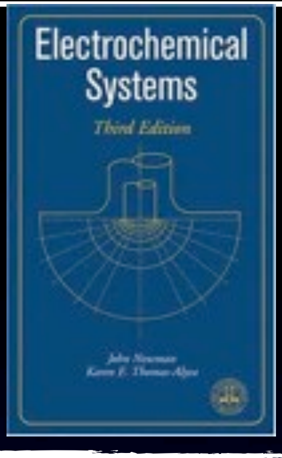
History of battery research at LBNL

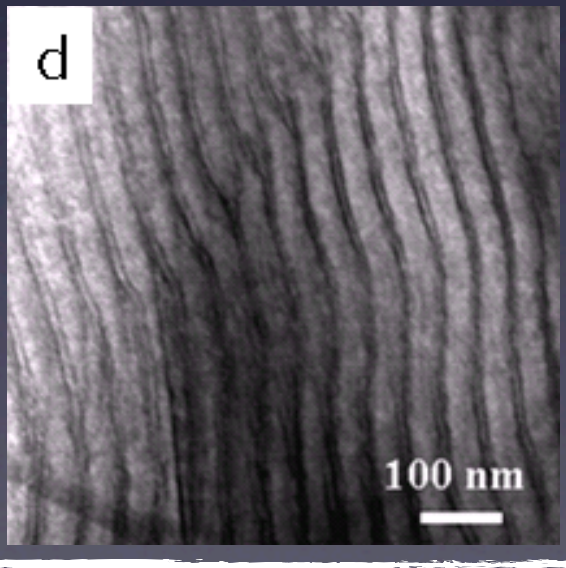


Performed the early experiments on non-aqueous electrolytes and ushered in the lithium battery

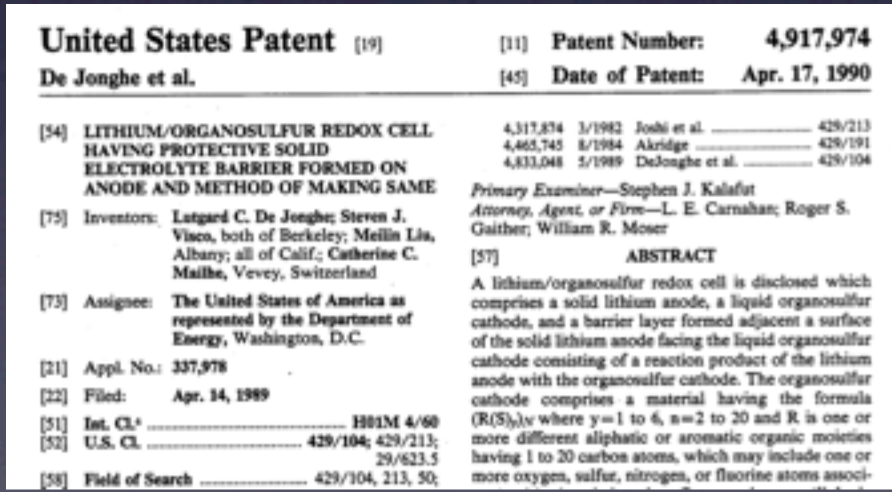


Formalized electrochemical engineering as a field

Pioneered the use of spectroscopic analysis of electrochemical systems



Developed a polymer that could revolutionize battery separators



United States Patent [19] — **De Jonghe et al.**

[11] **Patent Number: 4,917,974**
[45] **Date of Patent: Apr. 17, 1990**

[54] **LITHIUM/ORGANOSULFUR REDOX CELL HAVING PROTECTIVE SOLID ELECTROLYTE BARRIER FORMED ON ANODE AND METHOD OF MAKING SAME**

[75] Inventors: **Lutgard C. De Jonghe; Steven J. Visco**, both of Berkeley; **Meilin Liu**, Albany; all of Calif.; **Catherine C. Mailhe**, Vevey, Switzerland

[73] Assignee: **The United States of America as represented by the Department of Energy**, Washington, D.C.

[21] Appl. No.: **337,978**

[22] Filed: **Apr. 14, 1989**

[51] **Int. Cl.**[4] **H01M 4/60**
[52] **U.S. Cl.** **429/104**; 429/213; 29/623.5
[58] **Field of Search** 429/104, 213, 50;

4,317,874	3/1982	Joshi et al.	429/213
4,465,745	8/1984	Akridge	429/191
4,833,048	5/1989	DeJonghe et al.	429/104

Primary Examiner—Stephen J. Kalafut
Attorney, Agent, or Firm—L. E. Carnahan; Roger S. Gaither; William R. Moser

[57] **ABSTRACT**

A lithium/organosulfur redox cell is disclosed which comprises a solid lithium anode, a liquid organosulfur cathode, and a barrier layer formed adjacent a surface of the solid lithium anode facing the liquid organosulfur cathode consisting of a reaction product of the lithium anode with the organosulfur cathode. The organosulfur cathode comprises a material having the formula $(R(S)_y)_n$ where y=1 to 6, n=2 to 20 and R is one or more different aliphatic or aromatic organic moieties having 1 to 20 carbon atoms, which may include one or more oxygen, sulfur, nitrogen, or fluorine atoms associ-

Developed a concept to protect lithium metal; may hold the key to future batteries

Collaborators

BERKELEY LAB
Lawrence Berkeley National Laboratory

Batteries for Advanced Transportation Technologies (BATT)

Massachusetts Institute of Technology

Argonne NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

STONY BROOK UNIVERSITY

University of Pittsburgh

THE UNIVERSITY OF RHODE ISLAND

BINGHAMTON UNIVERSITY State University of New York

BERKELEY LAB

THE UNIVERSITY OF UTAH

MICHIGAN

CASE WESTERN RESERVE UNIVERSITY EST. 1826

ASU ARIZONA STATE UNIVERSITY

Hydro Québec

NREL National Renewable Energy Laboratory Innovation for Our Energy Future

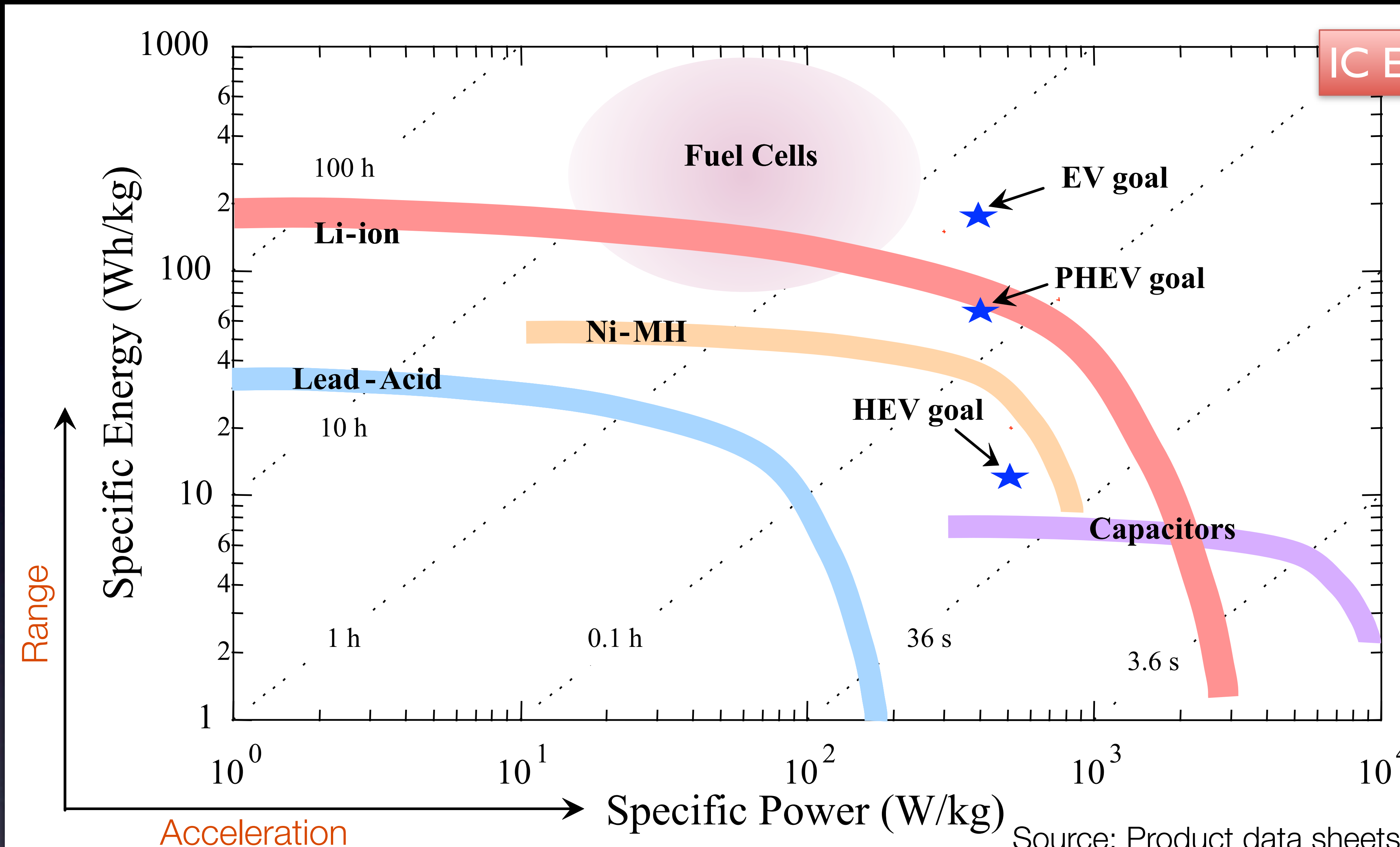
SwRI

PENNSTATE 1855

STANFORD UNIVERSITY

Drexel UNIVERSITY

Energy/power Interplay

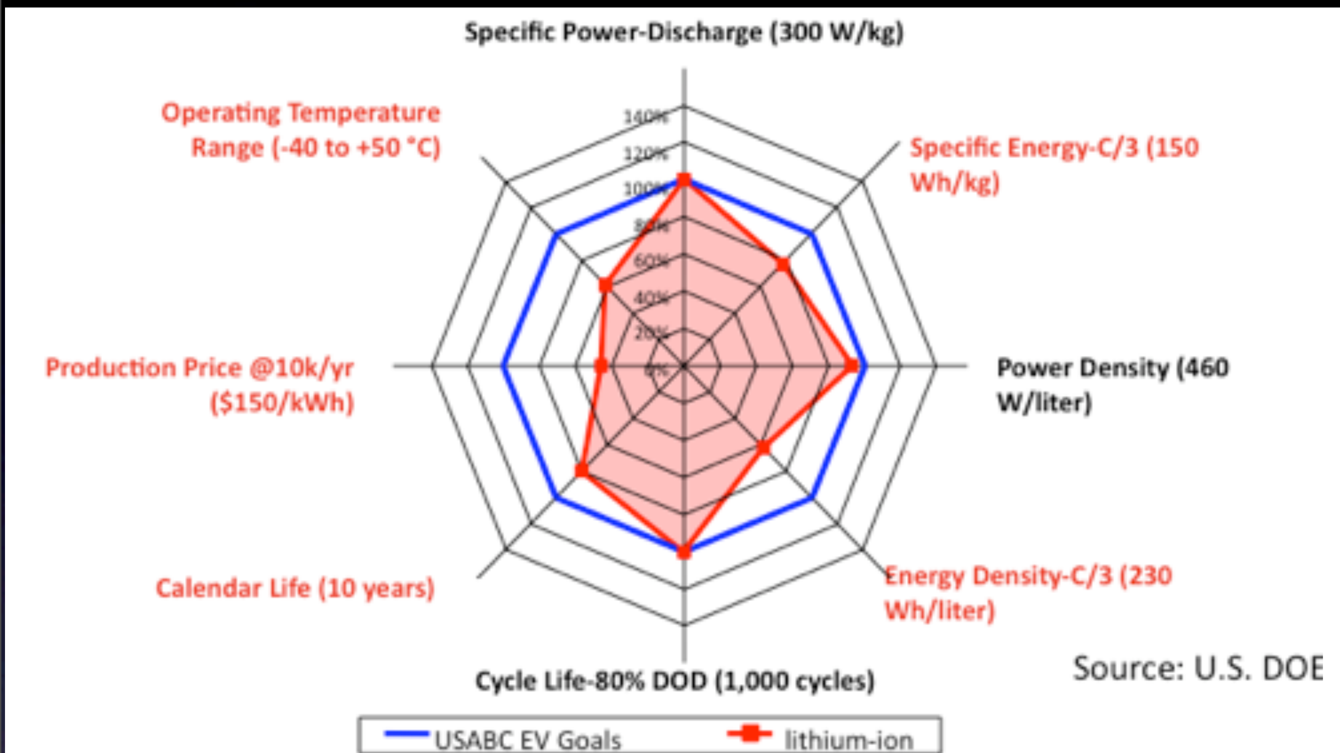


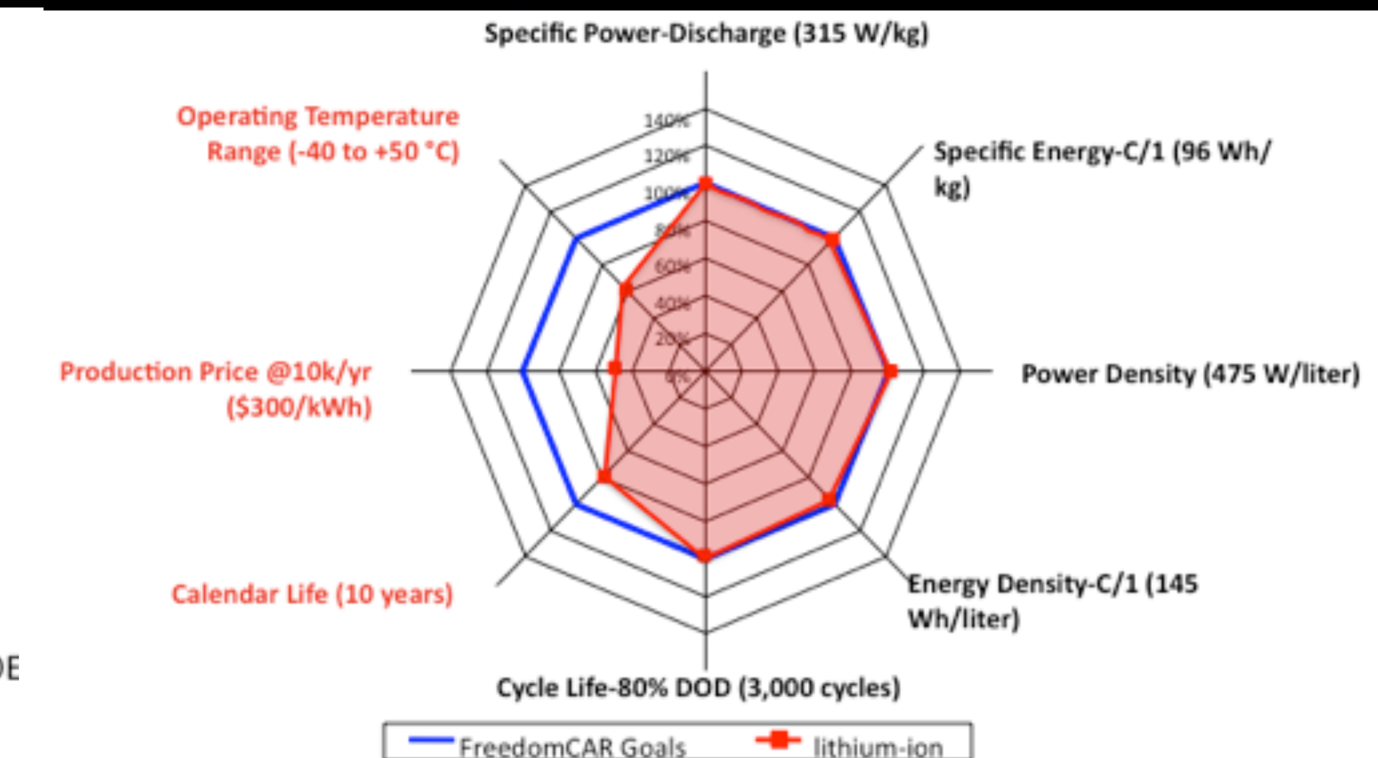
IC Engine=2500 Wh/kg

EV – Electric Vehicle
HEV – Hybrid-Electric Vehicle
PHEV– Plug-in Hybrid-Electric Vehicle

- Time of discharge a critical parameter for choice of storage system
- For storing of renewable energy, weight or volume not as critical (atleast in the US).
- Grid storage cuts across all times of discharge. See http://www.electricitystorage.org/ESA/home/

Status of batteries for vehicles





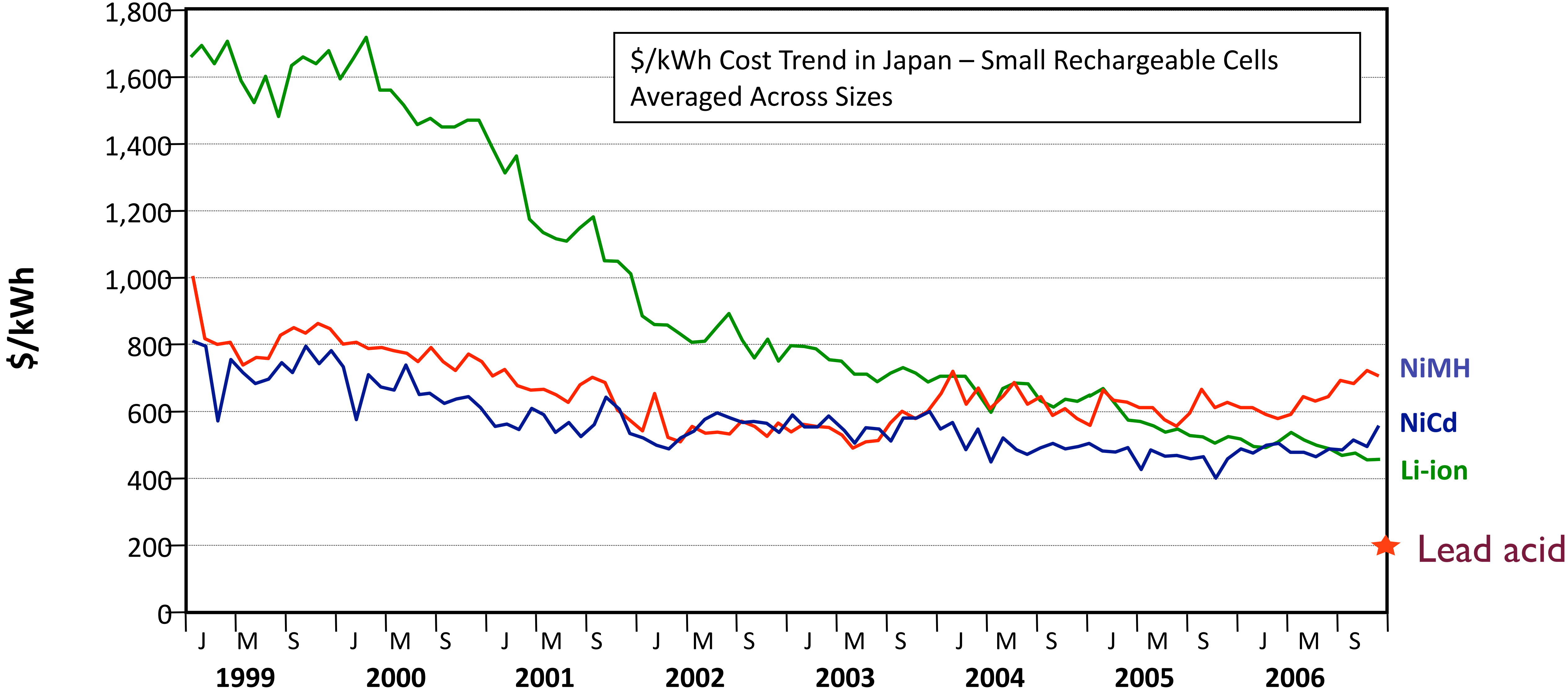
EV Status

PHEV Status

- Batteries are a compromise between performance, cost, life, and safety
- Requirements not as well defined for grid-storage applications

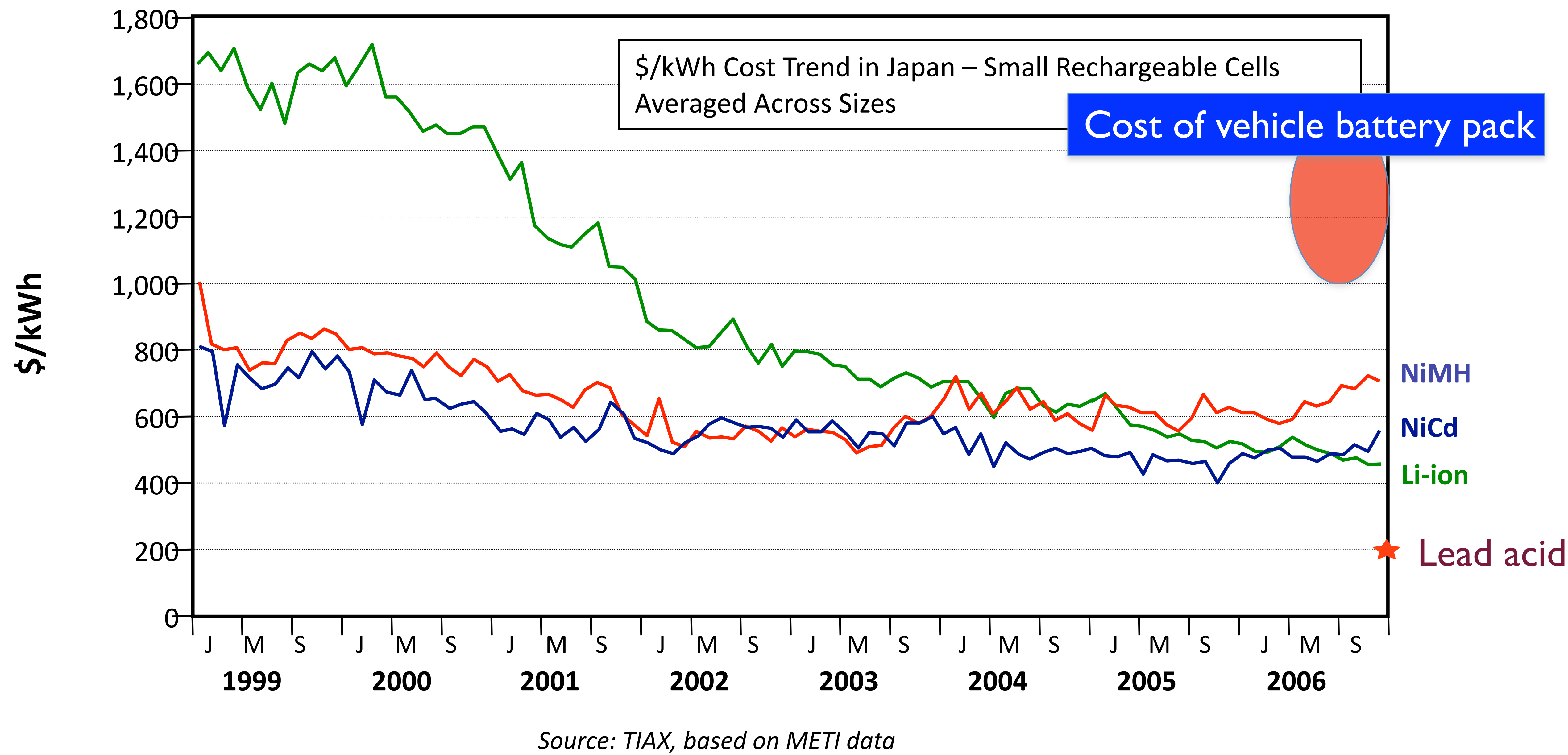
As of today, no one chemistry has all the necessary attributes

Cost of consumer electronics batteries



Source: TIAX, based on METI data

Cost of consumer electronics batteries



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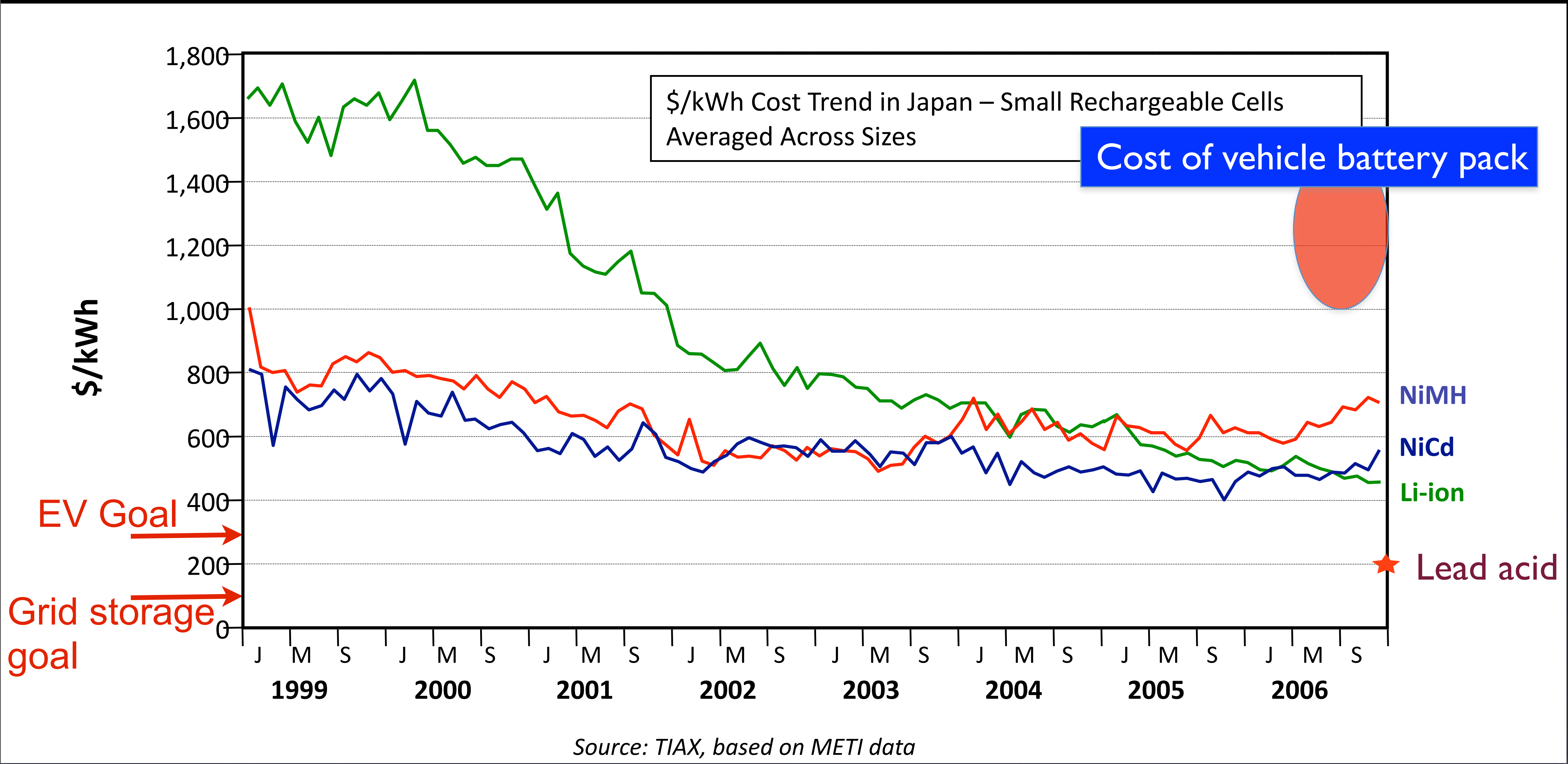
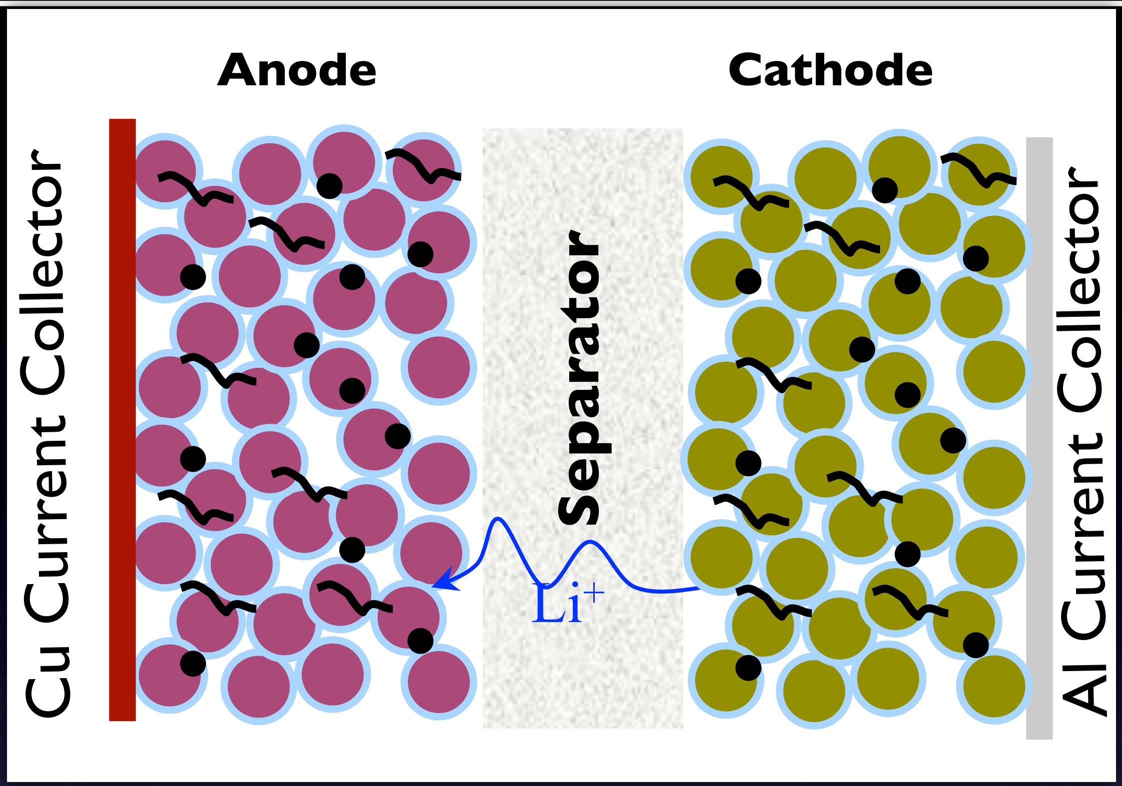


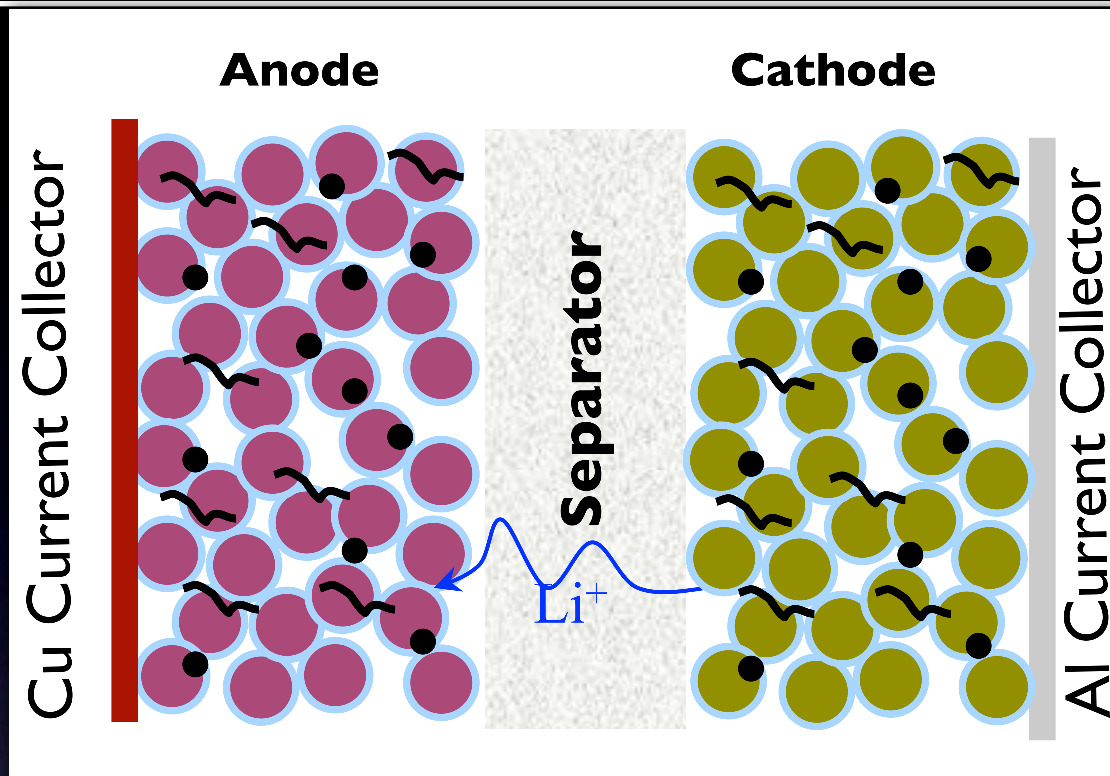
A Li-ion battery, as it is made today, will not be cost effective for most grid applications

Systems under consideration



Container batteries- High energy density
Cost scales with size.
Small discharge times

Systems under consideration



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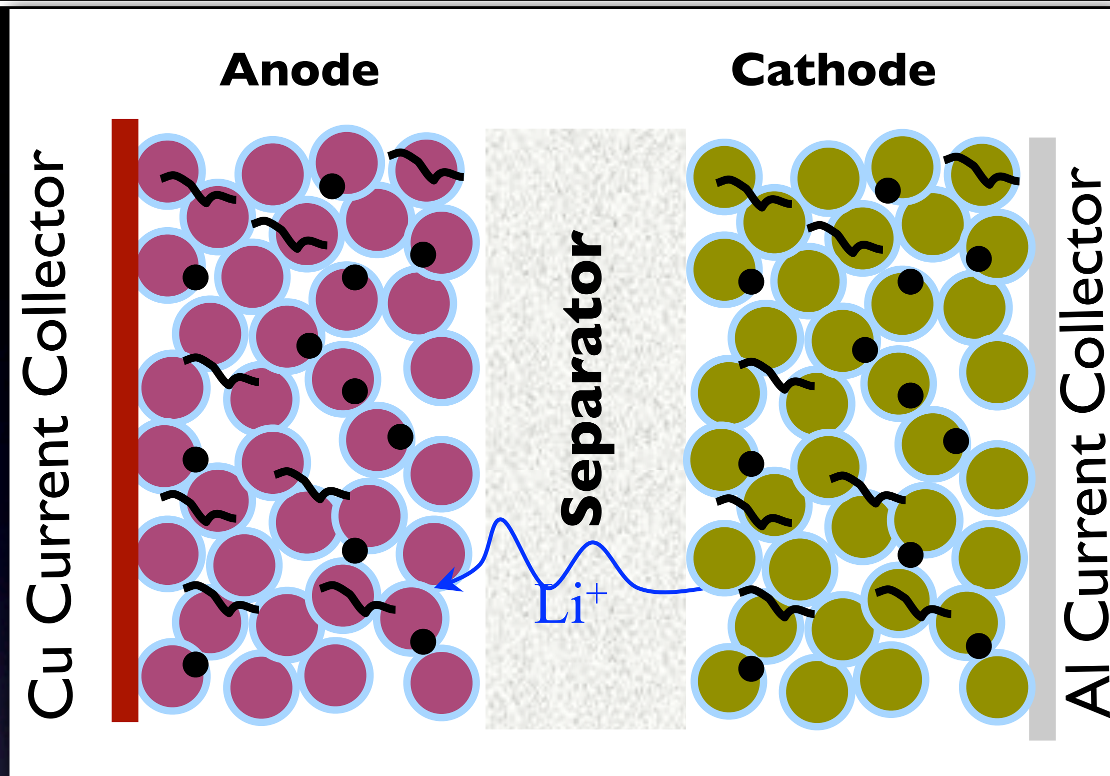
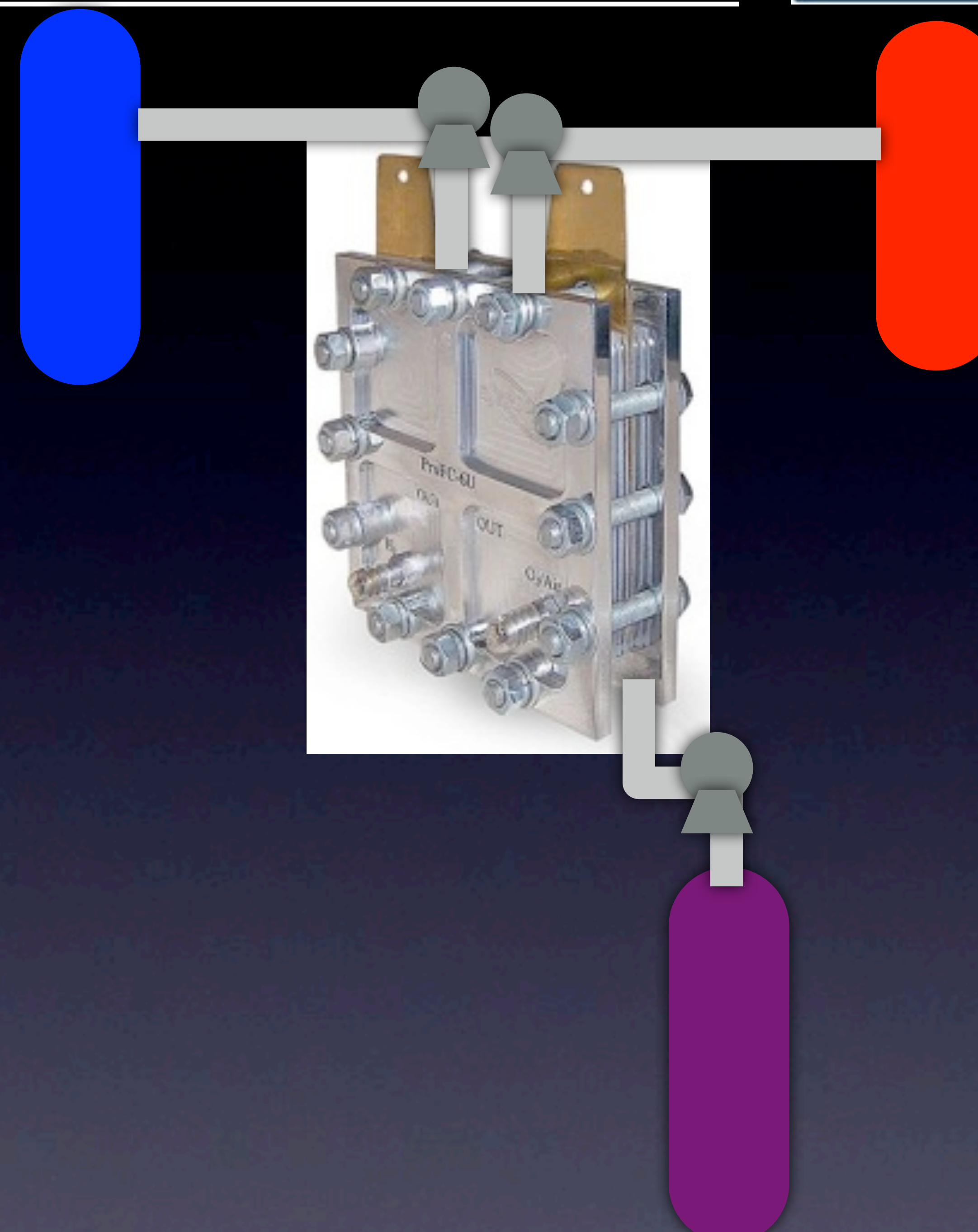
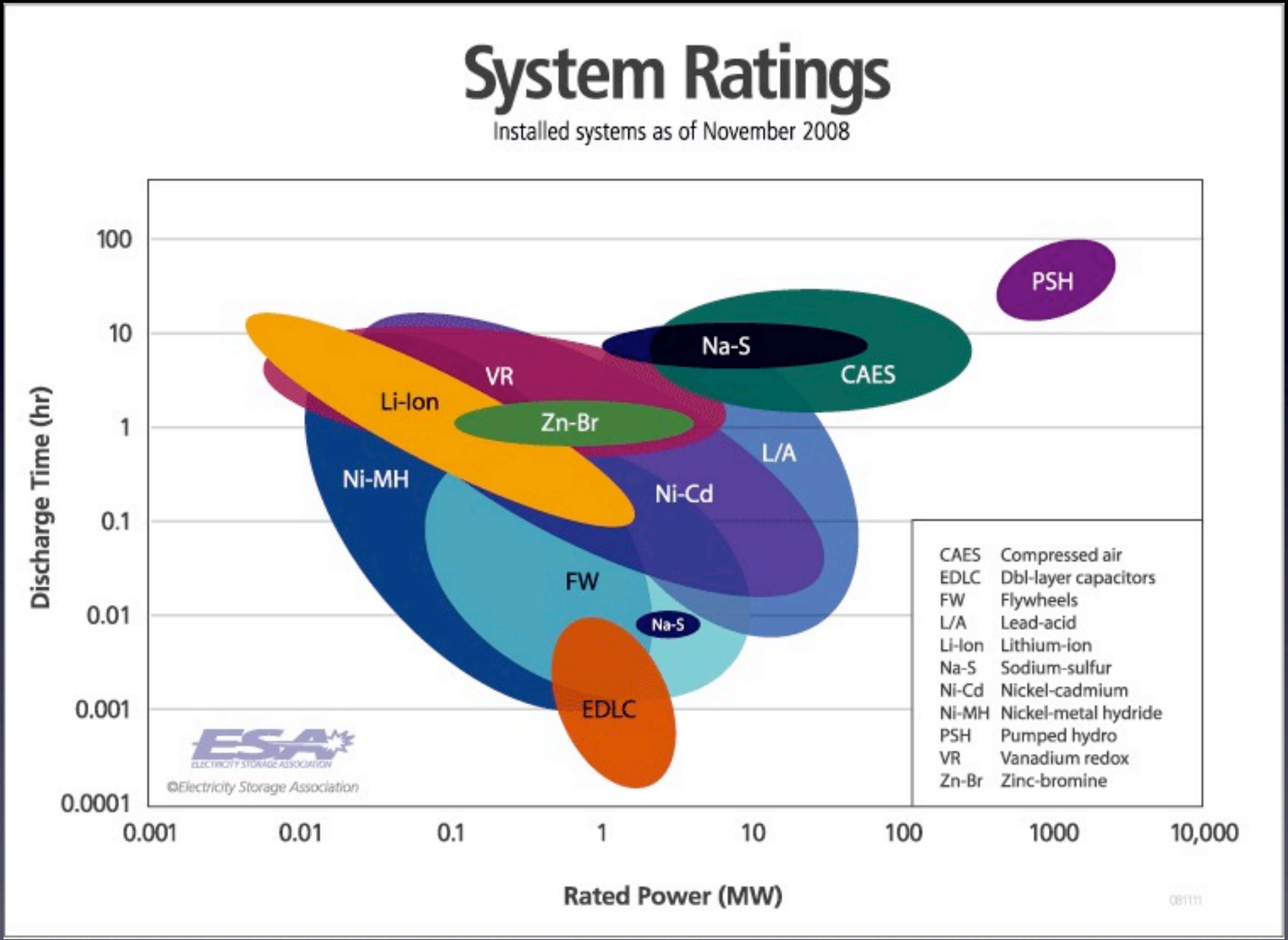




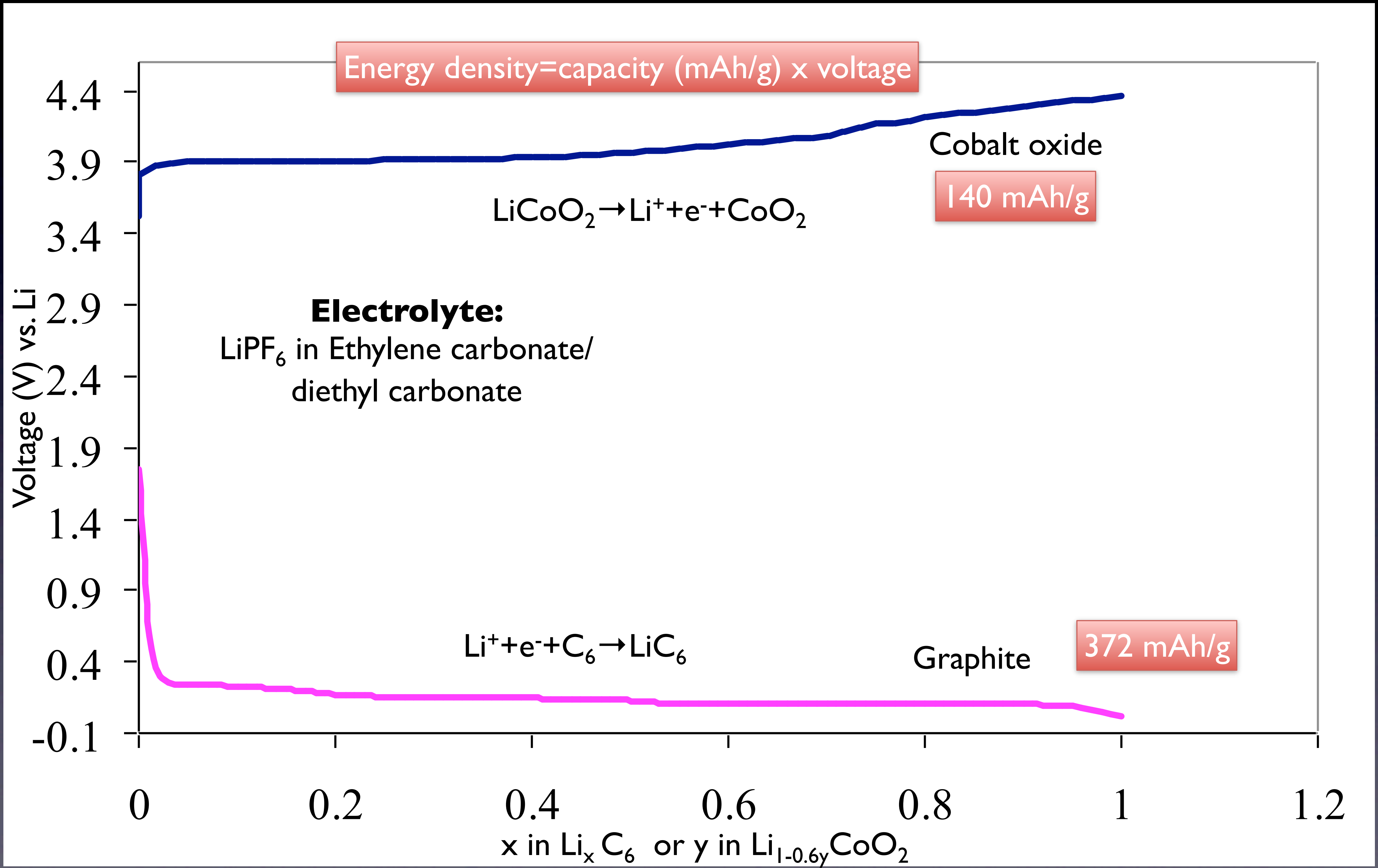
Container batteries- High energy density
Cost scales with size.
Small discharge times

Flow batteries-Low energy density
Lower cost for larger systems
Longer discharge times

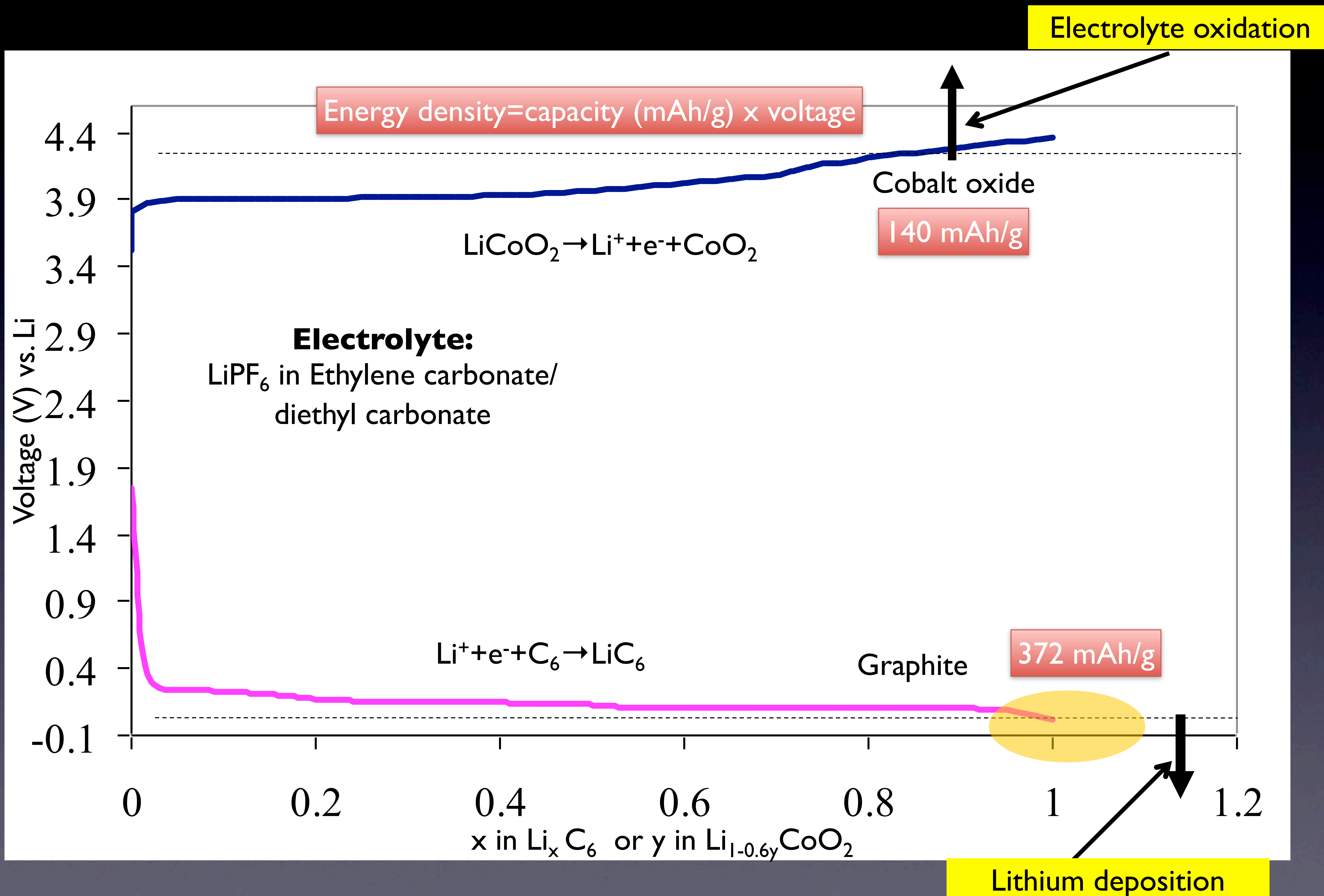
Batteries considered for grid-scale storage



How does a battery operate?



How does a battery operate?



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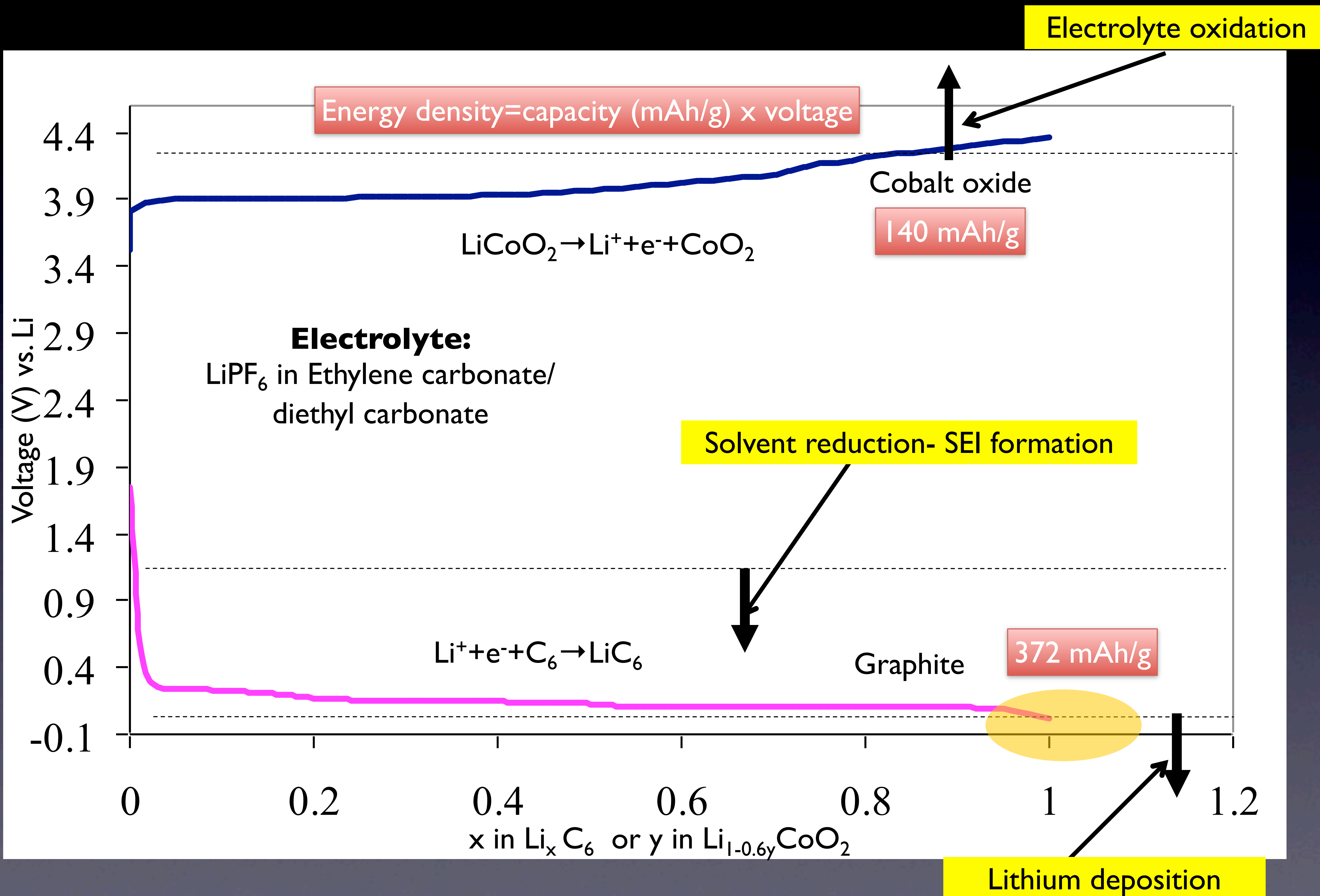
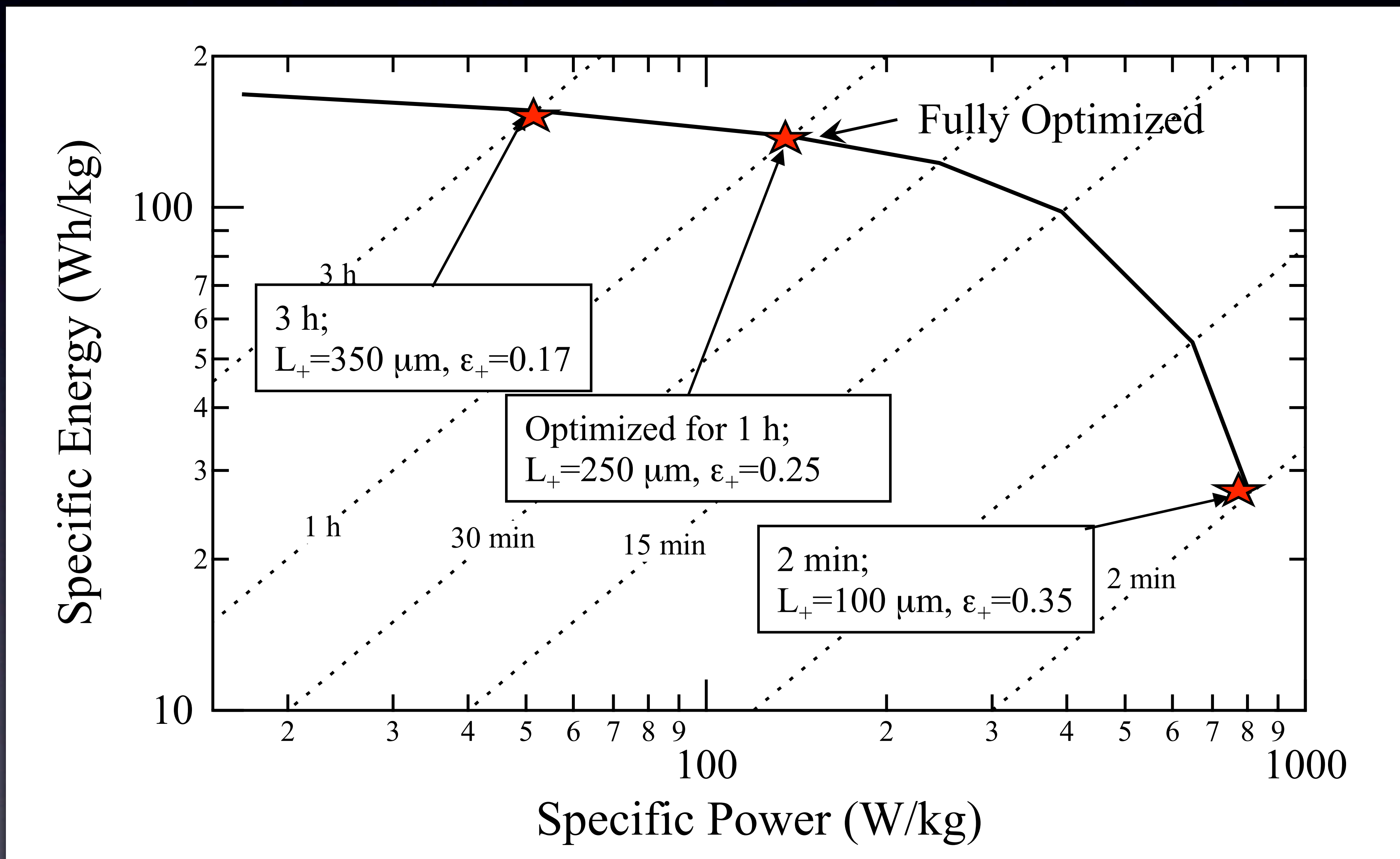
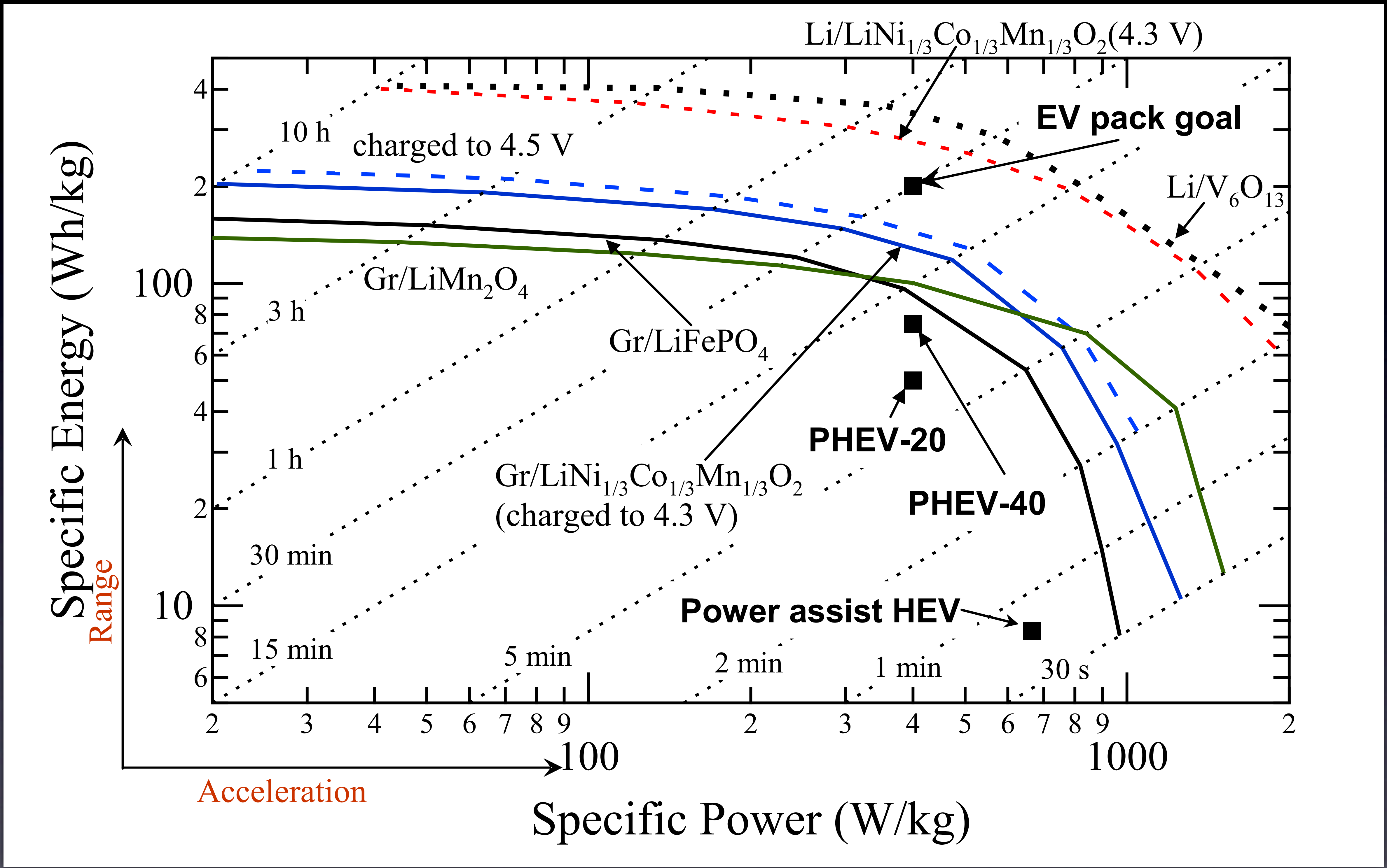


How to design a battery?

- LBNL has pioneered the use of mathematical tools to design batteries



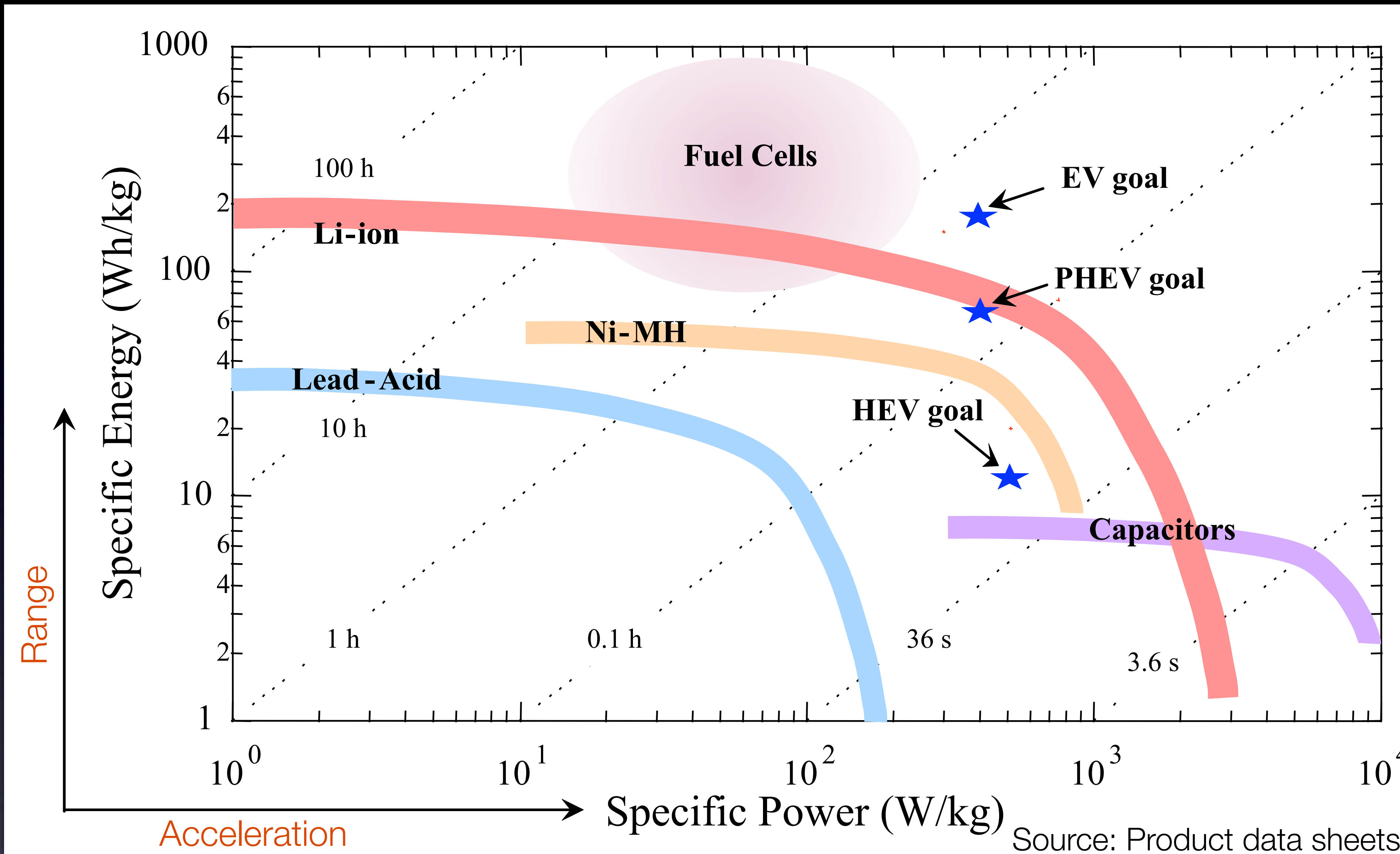
Models as a comparative tool



- Cost, life, and safety also need to be considered

Energy/power interplay

IC Engine=2500 Wh/kg



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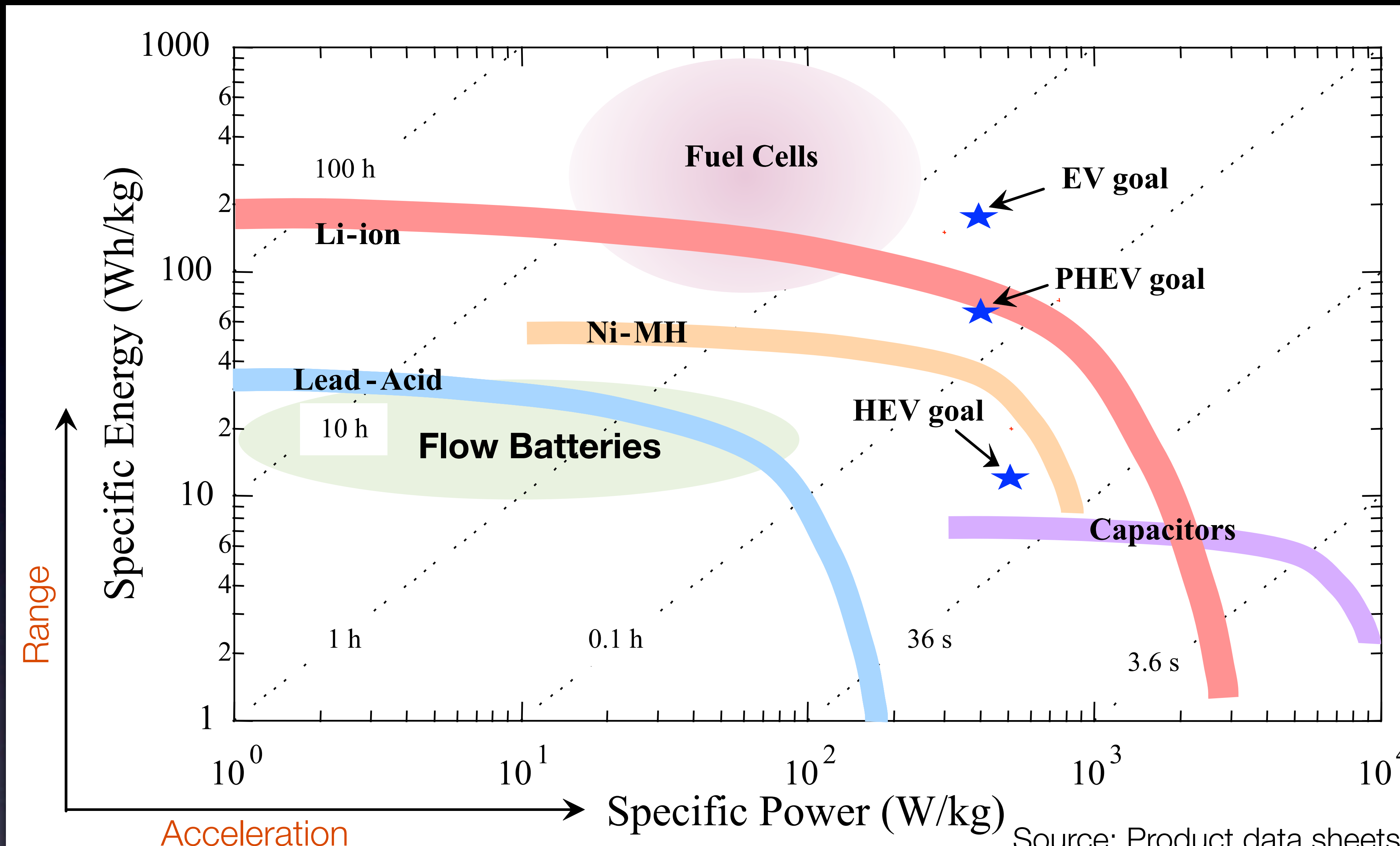
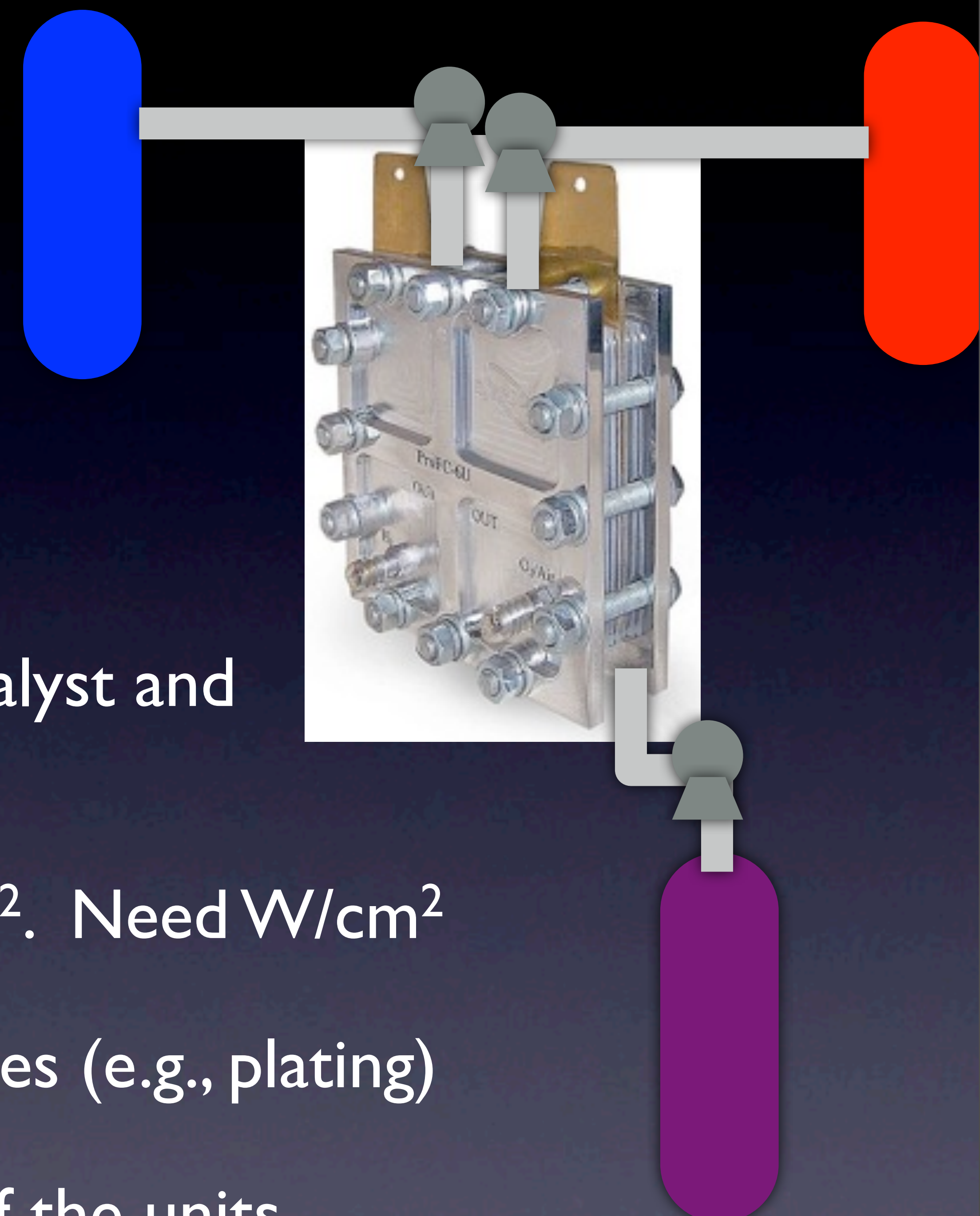


- Flow batteries not high in energy density
- However, for large discharge times, they can be made very inexpensive

How to choose a flow battery?

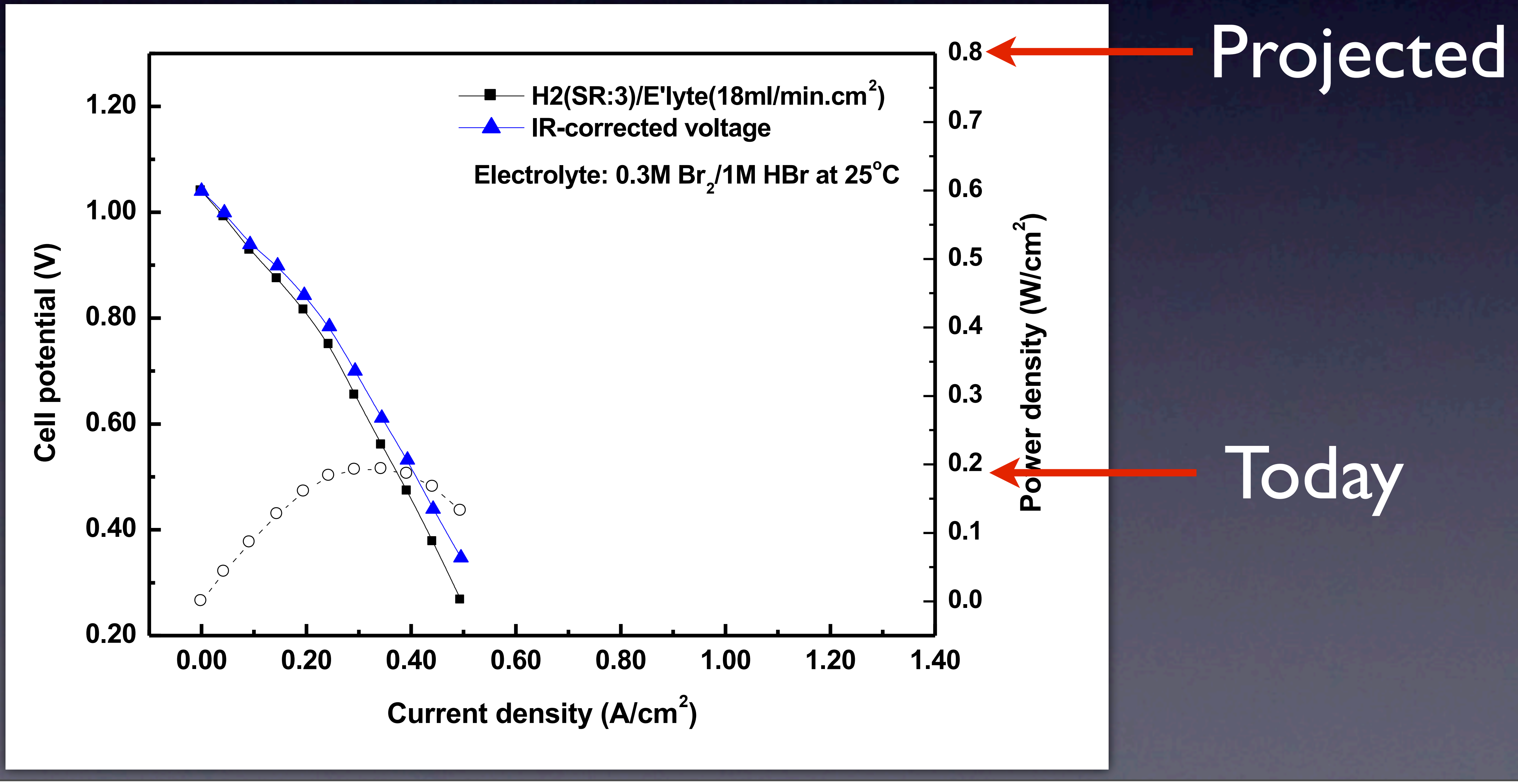


1. Need chemicals that are inexpensive
2. Need system with high reversibility
3. Need inexpensive catalyst and membranes
4. Need a high power device
   - Higher the power, smaller the amount of catalyst and membrane
   - Present day flow batteries ~ 50-100 mW/cm^2. Need W/cm^2
5. Chemistry should not lead to structural changes (e.g., plating)
6. Safety critical, especially considering the size of the units

Flow batteries are also all about compromise

The LBNL approach

- Choose chemicals that are inexpensive and abundant
- Ensure that chosen chemistry is highly reversible
- Design the battery to ensure that very high power can be obtained



Summary

- Choice of battery depends on the application
  - A chemistry that is ideal for, say, vehicle applications, may not be the best for grid storage

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- It takes ~10 years for a battery to develop from research to commercialization
  - It also takes major capital investments

Summary

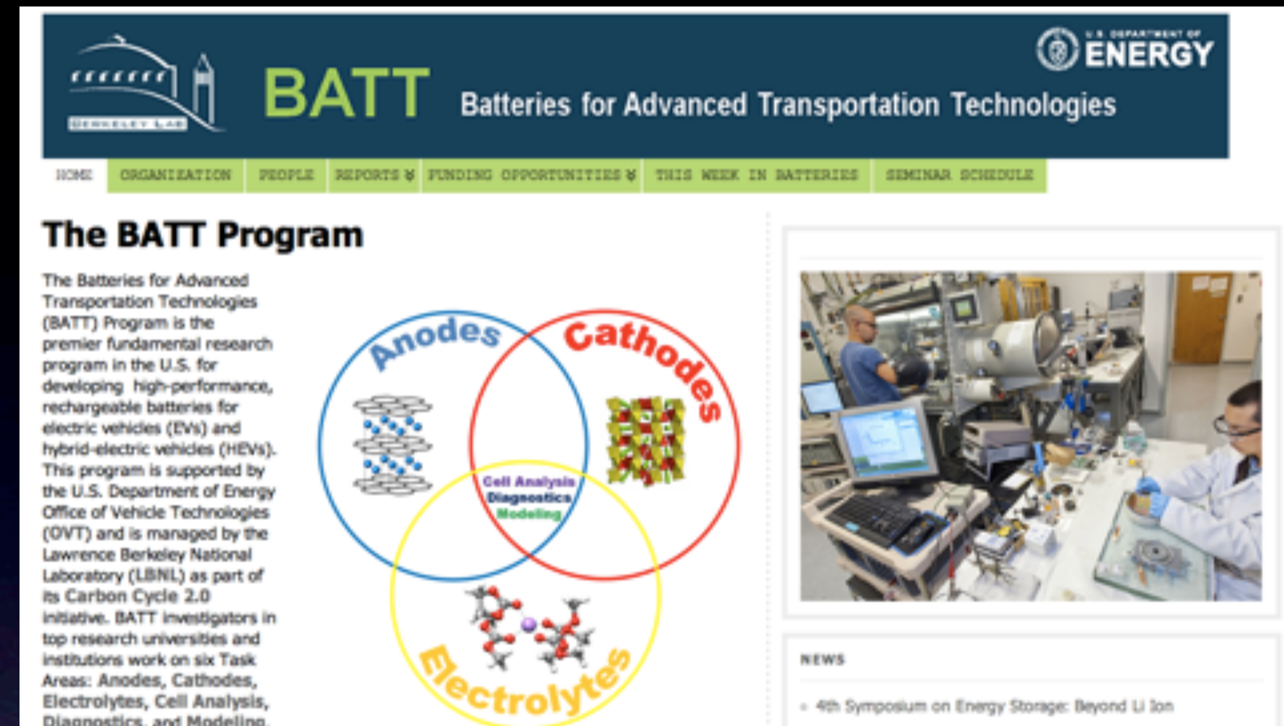
- Choice of battery depends on the application
  - A chemistry that is ideal for, say, vehicle applications, may not be the best for grid storage
- It takes ~10 years for a battery to develop from research to commercialization
  - It also takes major capital investments
- Batteries are all about compromise

Summary

- Choice of battery depends on the application
  - A chemistry that is ideal for, say, vehicle applications, may not be the best for grid storage
- It takes ~10 years for a battery to develop from research to commercialization
  - It also takes major capital investments
- Batteries are all about compromise
- Comparing various batteries can be challenging, especially early in development
  - Mathematical tools can be invaluable

More information

- Batteries for Advanced Transportation Technologies (BATT) Program website: http://batt.lbl.gov/



- Blog on batteries, “This week in batteries”: http://thisweekinbatteries.blogspot.com/